Melting of flat dust cluster due to parametric instability caused by nanosecond electric pulses

L.M.Vasilyak[1], V.E. Fortov, G.E. Morfill[2], A.V. Ivlev[2], M.Y. Pustylnik[2], D.N. Polyakov[1], H.M. Thomas[2], S.P. Vetchinin[1]

[1]Joint Institute for High Temperatures, Russian Academy of Sciences, Izhorskaya 13/19, 125412 Moscow, Russia.
vasilyak@ihed.ras.ru
[2]Max-Planck-Institut fur Extraterrestrische Physik, Giessenbachstrasse, 85741 Garching, Germany

Influence of high voltage 2-11 kV pulses of 20 nanosecond duration on the dynamics of the charged microparticles in 2-D cluster levitating in rf-plasma is studied. Application of repetitive pulses produces the vertical oscillations of the microparticles. The amplitude of the oscillations of the microparticles grows with the pulse amplitude. The nanosecond pulses may produce strong instabilities in the 2-D dust clusters. The instability has thresholds on both the frequency and amplitude of the external force and consequently is classified as a parametric instability. We found that the nanosecond pulses affect the horizontal cluster modes indirectly via the vertical oscillations. The instability occurs only if the repetition rate of the pulses is close to the vertical resonance frequency and the vertical resonance frequency is close to the doubled frequency of one of the horizontal modes of the cluster. Evolution of the total kinetic energy for the cluster during the instability is investigated. In the initial phase the kinetic energy oscillates around a certain value and its amplitude grows very slowly. At a certain moment it goes into the exponential growth phase and then saturates. Flat clusters, consisting of small number of microparticles exhibit parametric instabilities of horizontal modes under the effect of repetitive pulses. It was shown that the parametric instability is caused by the vertical oscillations of the microparticles in the nonuniform electric field environment of the sheath. Kinetic energy of dusty cluster particles increases due to parametric instability, and melting of the flat crystal cluster may happen. We suggested next mechanism of action. 1. Heating of plasma electrons by ns HV pulse. 2. Additional charging of dust particles by fast electrons. 3. Disequilibrium in trap due to additional force in vertical direction. 4. Charge relaxation by means of ions flow. 5. Particle disequilibrium in horizontal level as a result of vertical displacement. 6. Instability in horizontal level. 7. Rise of kinetic energy of dusty cluster particles due to parametric instability. 8. Melting of flat crystal cluster. This process is possible if the eigenfrequency of dust particles oscillations in horizontal level is the function of height and the dust particle oscillates vertically.